



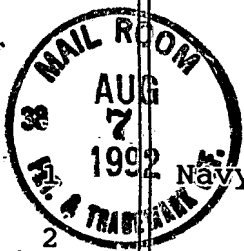
N.C. 72939

CLOSED BRAYTON CYCLE DIRECT CONTACT REACTOR/STORAGE TANK
WITH O₂ AFTERBURNER (

TO ALL WHOM IT MAY CONCERN

BE IT KNOWN THAT PAUL M. DUNN employee of the United States Government, citizen of the United States of America, and resident of Wakefield, County of Washington, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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Navy Case No. 72939

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CLOSED BRAYTON CYCLE DIRECT CONTACT REACTOR/STORAGE TANK
WITH O₂ AFTERBURNER

This patent application is copending with the related applications by the same inventor filed on the same date as subject patent entitled Closed Cycle Brayton Propulsion System with Direct Heat Transfer, identified as Navy Case No. 71843, Closed Brayton Cycle Direct Contact Reactor/Storage Tank with Chemical Scrubber, identified as Navy Case No. 72910, Closed Cycle Brayton Power System with Direct Heat Transfer, identified as Navy Case No. 73348, and Semiclosed Brayton Cycle ^{Power System} with Direct Combustion Heat Transfer, identified as Navy Case No. 73825.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to metal vapor control of the liquid metal fuel used in a direct contact Brayton cycle power system. More particularly the invention relates to a system for

1 eliminating metal vapor at the working gas outlet of a closed
2 Brayton cycle direct contact reactor/storage tank by use of an O₂
3 afterburner.

4 (2) Description of the Prior Art

5 My invention titled Closed Cycle Brayton Propulsion System
6 with Direct Heat Transfer, with which this application is
7 copending, discloses the use of the more efficient Brayton cycle
8 instead the Rankine cycle in a closed cycle underwater propulsion
9 system. The size and weight penalty of the Brayton cycle's hot
10 side heat exchanger is eliminated by use of direct contact heat
11 transfer between the working fluid which is an inert gas such as
12 helium, argon, xenon, or a mixture of inert gases, and a liquid
13 metal bath of a material such as lithium, sodium, potassium,
14 aluminum, magnesium, or an alloy thereof.

15 The closed cycle Brayton power system with direct heat
16 transfer invention as disclosed in copending application, Navy
17 Case No. 71843, has the problem that some of the liquid metal
18 fuel vapor will be carried from the reactor/fuel exchanger into
19 the working fluid stream. The volume fraction of metal vapor is
20 relatively low; however, during a long run of the power cycle the
21 metal accumulation can damage the regenerator, cooler, turbine,
22 or compressor. The volume fraction of the vapor present is equal
23 to the ratio of the partial pressure of the liquid metal to the
24 system operating pressure, i.e. for aluminum @ 2343°F, 1mm
25 Hg/~800 psi = 1.6×10^{-6} , for lithium @ 2323°F, 400 mm Hg/~800
26 psi = 6.5×10^{-4} .

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These and other objects are accomplished with the present invention by providing a system in which O_2 is fed into the reactor/storage tank's filter cavity. This causes the metal vapors in the circulating working fluid stream to react directly with the O_2 forming a low volume of solid oxide particles at the closed Brayton cycle operating temperatures and pressures. These solid oxide particles settle out of the working gas before it exits the filter cavity.

A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

1 FIG. 1 is a diagram of a closed Brayton direct contact
2 reactor/storage tank with an O₂ afterburner in accordance with
3 the present invention.
4

5 DESCRIPTION OF THE PREFERRED EMBODIMENT

6 Referring now to FIG. 1 there is shown a reactor/storage
7 tank 10 for transferring heat from a liquid metal fuel 12 to a
8 working gas in a closed Brayton cycle power system. Although the
9 terminology reactor/storage tank and direct contact
10 reactor/storage tank are used to describe component 10, names
11 such as heater/reactor housing and direct contact heater could be
12 used.

13 In the preferred embodiment, a direct contact, metal
14 reactor/storage tank is partially filled with a liquid metal fuel
15 12. Reactor/storage tank 10 has a working gas inlet 14 tube
16 disposed in reactor/storage tank 10 below the surface 12a of
17 liquid metal fuel 12 for the injection of the working gas
18 directly into liquid metal fuel 12. Working gas inlet 14 is a
19 tube extending into reactor/storage tank 10 with a plurality of
20 apertures 14a therein, disposed along the length thereof.
21 Similarly, a working gas outlet tube 16 is disposed in
22 reactor/storage tank 10 above surface 12a of liquid metal fuel 12
23 for the ejection of the working gas from reactor/storage tank 10.
24 The flow of the working gas is designated generally by flow
25 arrows 18. Also disposed within reactor/storage tank 10 is an
26 oxidant injector tube 20. An oxidant is introduced through

1 injector tube 20 into liquid metal fuel 12 where it reacts with
2 fuel 12 to produce heat. An afterburner oxygen injector tube 22
3 is disposed in a filter cavity 24 above the surface 12a of liquid
4 metal fuel 12 for supplying an oxidant to filter cavity 24. An
5 electrically controllable oxidant injector control valve 26
6 communicates with ^{an} oxidant source ²⁷ ~~(not shown)~~ for supplying an
7 oxidant to afterburner oxidant injector 22 in filter cavity 24.

8 The oxidizing agent or oxidant in the preferred embodiment
9 is oxygen, O₂. The reaction between oxygen and an aluminum-
10 magnesium alloy liquid metal fuel provides the preferred means of
11 generating heat within reactor/storage tank 10. The working gas
12 is normally argon or a mixture of helium and xenon. Helium,
13 argon and xenon are inert gases and therefore do not react with a
14 metal fuel. Other possible choices for metal fuels include
15 alkali metals, such as lithium, sodium or potassium.

16 Disposed within the reactor/storage tank 10 between liquid
17 metal fuel 12 and working gas outlet tube 16 is a screen assembly
18 28 for preventing liquid metal fuel 12 from splattering into
19 working gas outlet tube 16. A filter 30, which further prevents
20 contaminants within the working gas from entering working gas
21 outlet tube 16, is disposed between screen assembly 28 and
22 working gas outlet tube 16. Typically, filter 30 is a ceramic
23 fiber insulation filter.

24 In operation, after the metal fuel is heated to the liquid
25 state, the working gas is injected through working gas inlet 14
26 into reactor/storage tank 10. The working gas then bubbles

1 through liquid metal fuel 12. Representative working gas bubbles
2 32 are shown leaving aperture 14a and expanding toward surface
3 12a of liquid metal fuel 12. Heat is transferred directly from
4 liquid metal fuel 12 to the working gas. During this process
5 metal vapors are formed.

6 When the oxidant, preferably O_2 , is injected into filter
7 cavity 24 the metal vapors react directly with the oxidant while
8 still inside filter cavity 24. The small volume of solid metal
9 oxide formed precipitates from the working gas, and remains on
10 filter 30, thereby removing the metal vapors from the working
11 fluid. A high temperature oxidant sensor 34, such as is used in
12 automotive emission controls, and a temperature sensor 36 are
13 disposed within working gas outlet 16 for detecting the presence
14 of an oxidant in the exit stream. Oxidant sensor 34 and
15 temperature sensor 36 are electrically connected to a valve
16 controller 38 by oxidant sensor connection 40 and temperature
17 sensor connection 42. Valve controller 38 is electrically
18 connected to oxidant injector control valve 26 by valve control
19 cable 44. Valve controller 38 reduces and increases the
20 afterburner oxidant flow in response to the readings from oxidant
21 sensor 34 and temperature sensor 36 to give a constant but very
22 low concentration of oxidant in the exit gas stream.

23 The combination of screen assembly 28, filter 30 and the
24 afterburner injector tube 22 effectively clean the working gas
25 before it passes through outlet tube 16.

1 In alternative embodiments, the liquid fuel can be one of
2 the alkali metals such as lithium, sodium, or potassium, and the
3 oxidant can be a chlorofluorocarbon, such as $C_2F_3Cl_3$ known in the
4 art as Freon-13. Chlorofluorocarbon oxidants cannot be used with
5 aluminum-magnesium fuel, however, because the products of the
6 oxidation reaction are gaseous at the operating temperature.

7 There has therefore been described a reactor/storage tank 10
8 that is used in a closed Brayton cycle. The reactor/storage tank
9 has an afterburner injector tube 22 in filter cavity 24 that
10 functions as an afterburner in the path of the working fluid to
11 eliminate metal vapor from the working fluid. In the absence of
12 this afterburner, any metal vapor present in the circulating
13 working fluid plates out and eventually freezes at a point in the
14 cycle where either the partial or total pressure of the gas
15 stream is reduced, or the gas is cooled below the melting point
16 of the vapor. These conditions occur in the turbine,
17 regenerator, and cooler of the direct contact Brayton power
18 cycle. The metal deposits can reduce heat transfer in the
19 regenerator, damage the turbine, or cause a pressure drop in any
20 of the components.

21 It will be understood that various changes in the details,
22 materials, steps and arrangement of parts, which have been herein
23 described and illustrated in order to explain the nature of the
24 invention, may be made by those skilled in the art within the
25 principle and scope of the invention as expressed in the appended
26 claims.